17:49:36 OCA PAD INITIATION - PROJECT HEADER INFORMATION 07/21/88

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Cost share #:
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Work type : RES
Contract#: AGR DTD 880718
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Contract entity: GTRC

Subprojects ? : N
Main project #:

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Unit code: 02.010.116
Project director(s):
BERGHAUS D G CE

Sponsor/division names: ELECTROMAGNETIC SCIENCES /
Sponsor/division codes: 254 / 004

Award period: 880621 to 880902 (performance) 880902 (reports)

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Funded	7,420.00	7,420.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: TENSILE AND SHEAR STRENGTHS OF STRUCTURAL ADHESIVES

PROJECT ADMINISTRATION DATA

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Security class (U,C,S,TS) : U
ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A
N/A supplemental sheet
Equipment title vests with: Sponsor X GIT
N/A NONE PROPOSED.

Administrative comments -
PROJECT INITIATION. NON-DISCLOSURE AGREEMENT APPLIES.

5/29/22

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Date 3/8/89

Project No. E-20-670 Center No. R6545-0A0

Project Director D. G. Berghaus School/Lab CE

Sponsor Electromagnetics Sciences

Contract/Grant No. Agreement dtd. 7/18/88 GTRC XX GIT ___

Prime Contract No. ___

Title Tensile and Shear Strengths of Structural Adhesives

Effective Completion Date 9/2/88 (Performance) 9/2/88 (Reports)

Closeout Actions Required:

___ None
X Final Invoice or Copy of Last Invoice
___ Final Report of Inventions and/or Subcontracts
___ Government Property Inventory & Related Certificate
___ Classified Material Certificate
___ Release and Assignment
___ Other ___

MAR 1989 RECEIVED SUPPORT SERVICES OCA

Includes Subproject No(s). ___

Subproject Under Main Project No. ___

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X Project File
X Contract Support Division (OCA) (2)
___ Other ___

Tensile and Shear Strengths of Structural Adhesives

by

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Abstract

The objective of this study was to determine shear and tensile strengths of structural adhesives used to bond materials in microwave assemblies. The materials included RTV 8262, Keene 6250 film, Scotchweld 2214 and Scotchweld 2216. These adhesives bonded ferrite to aluminum pieces in double lap shear and butt joint tensile test specimens. Some specimens were tested at low temperature extremes while others underwent thermal cycling prior to testing. Tests were performed using a rate controlled, displacement feedback MTS universal machine. All specimens were loaded to bond failure.

Most double lap shear specimens did not experience a simultaneous failure of both bonded sides. In most cases, one bond failed first and loading was continued to failure of the second. Consequently, most double lap shear specimens have different strength values for each of their two bonds. The difference in these failure stresses may be attributed to unsymmetric loading after the first bond failure or may indicate a bond integrity difference produced during specimen manufacturing.

Keene 6250 film produced the highest strength bonds of all adhesives tested at room temperature. More specifically, Keene 6250 film failed at stress levels greater than 2.5 times the next strongest adhesive during both shear and tensile testing. Only double lap shear specimens bonded with Scotchweld 2216 and tested at low temperature extremes failed at comparable stresses.

Introduction

Structural adhesives have been utilized by Electromagnetic Sciences Inc.(EMS) to bond materials in microwave assemblies. EMS has never experienced an adhesive failure in delivered hardware due to thermally or structurally induced loads, however, this test data provided quantitative information concerning the integrity of the adhesive bonds. The objective of this study was to determine shear and tensile strengths of structural adhesives currently employed, or under consideration for use in microwave assemblies.

The structural adhesives, RTV 8262, Keene 6250 film, Scotchweld 2214 and Scotchweld 2216 (with and without silver surface plating), bonded ferrite to aluminum pieces in double lap shear and butt-joint tensile specimens. Also tested were butt-joint specimens with a three layer teflon (Cuflon or Duroid) sandwich. Here, Keene 6250 film bonded the teflon layers to each other, while Scotchweld 2216 bonded the entire teflon sandwich between aluminum blocks. All tests were performed at room temperature with the exception of three Scotchweld 2216 double lap shear specimens. These were tested after a 24 hour cold temperature soak at approximately -20° C. Prior to testing, certain specimens had been thermally cycled, as given by table 1.

Table 1. Thermal Cycling Prior to Testing

ADHESIVE	SPECIMEN TYPE	NO. of SPECIMENS	NO. of CYCLES	TEMP RANGE
RTV 8250	BJ	4	40	-60° to 100° C
Keene 6250	BJ	2	40	-60° to 100° C
Scotchweld 2216	BJ	1	48	-20° to 60° C
"	DLS	2	56	-20° to 60° C
"	DLS	1	48	-20° to 60° C

BJ = Butt Joint DLS = Double Lap Shear

Materials and Methods

The double lap shear and butt joint tensile specimens were fabricated as indicated by figures 1 and 2 respectively. The structural adhesives bonded 0.125 in. thick ferrite pieces to aluminum with bond line thicknesses ranging from 0.001 to 0.002 in. The stripline butt joint specimens used Scotchweld 2216 to bond a 0.065 - 0.070 in. thick teflon sandwich between the aluminum blocks.

Grips to accommodate the double lap shear and butt joint tensile specimens were fabricated for use in a rate controlled, displacement feedback MTS machine (Figs. 3 and 4). All specimens were tested at a constant displacement rate and loaded to fracture.

Copper-Constantan thermocouples verified specimen temperatures during testing at low temperature extremes. Here, three double lap shear specimens bonded with Scotchweld 2216 were cold temperature soaked for 24 hours prior to testing. The specimens were placed in a freezer with thermocouple wires running from the interior of the freezer to a millivolt potentiometer kept at room temperature. Each specimen was taken directly from the freezer, immediately inserted into the testing machine and loaded to fracture. Table 2 gives specimen temperatures after the cold soak.

Table 2. Specimen Temperatures after 24 Hour Cold Soak

Specimen I.D.	Temp. after Soak
CLCS1	-22° C
CLCS2	-24° C
CLCS3	-16° C

Each specimen was coded with a series of initials indicating the structural adhesive, the testing temperature, lap shear vs. butt joint assembly and any prior thermal cycling. Table 3 gives coding definitions.

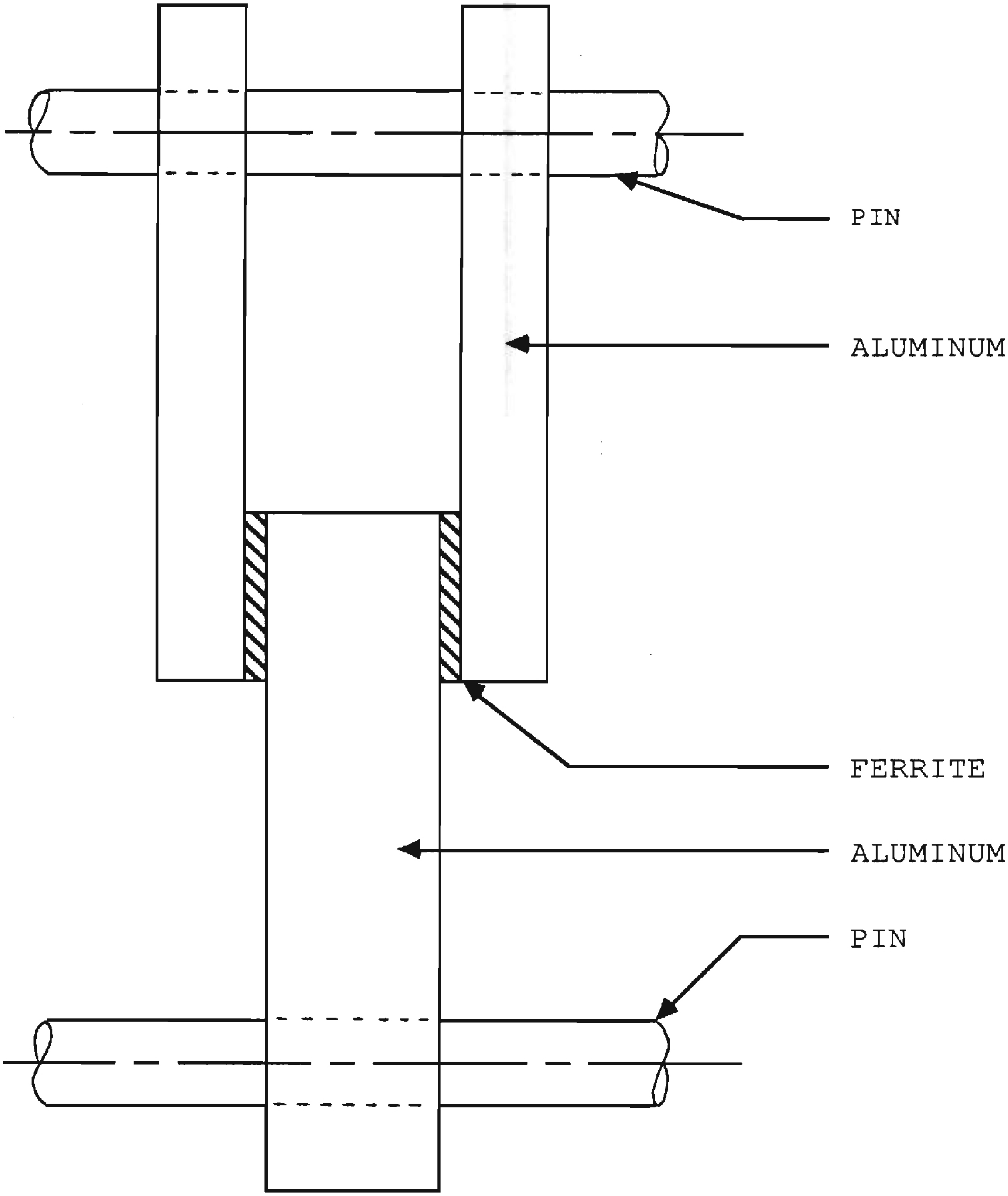

Figure 1. Double lap shear test specimen

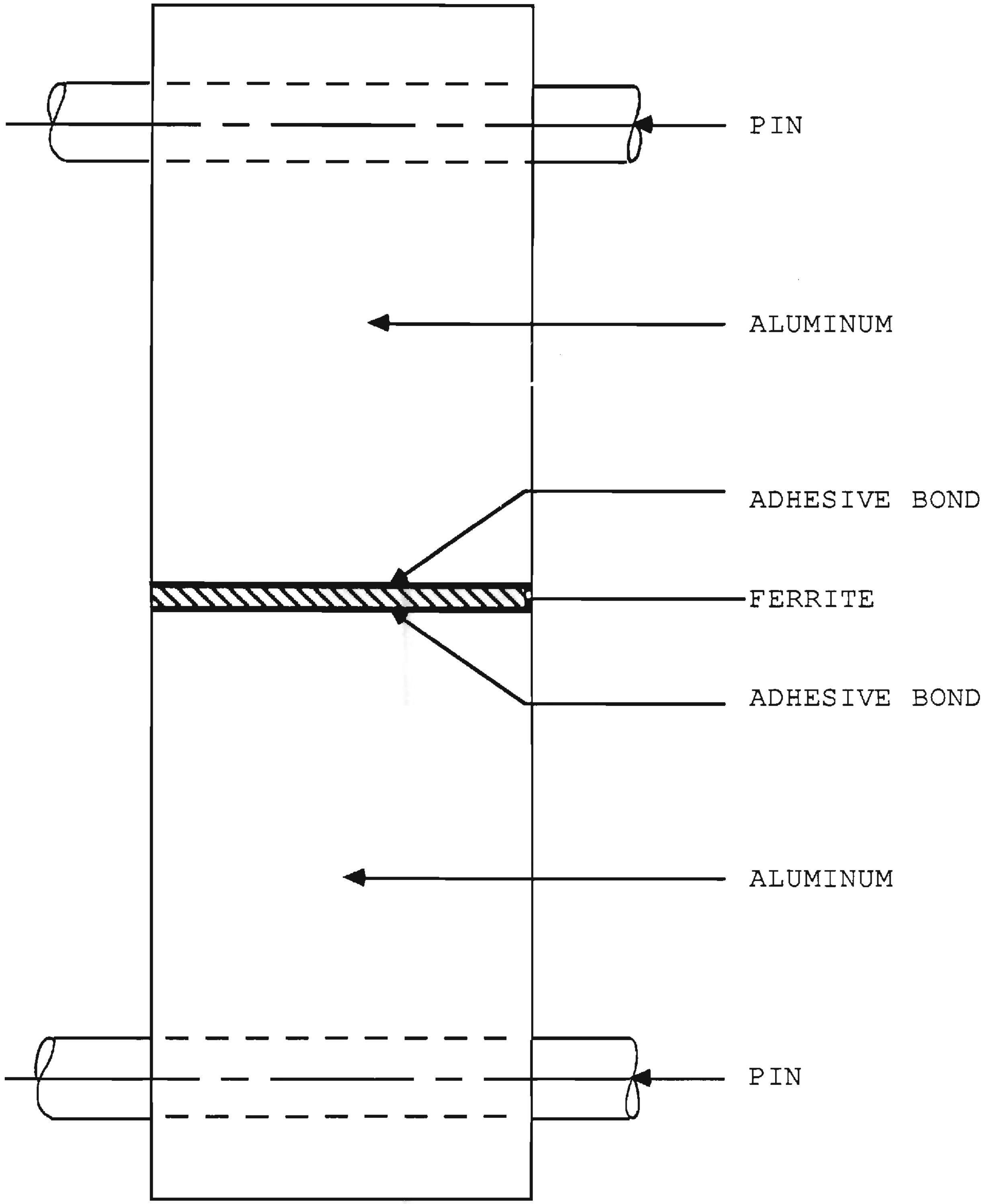

Figure 2. Butt joint specimen

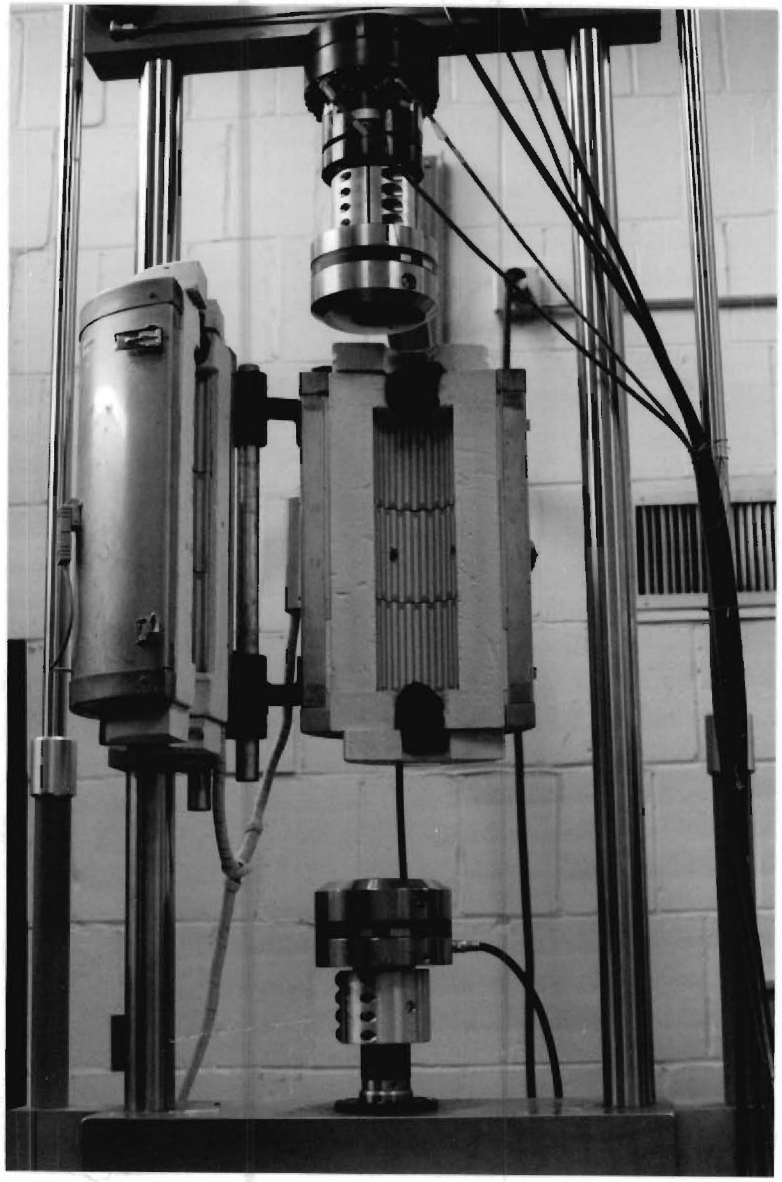

Figure 3. Load frame for rate controlled, displacement feedback MTS machine (High temperature chamber was not used for these experiments.)

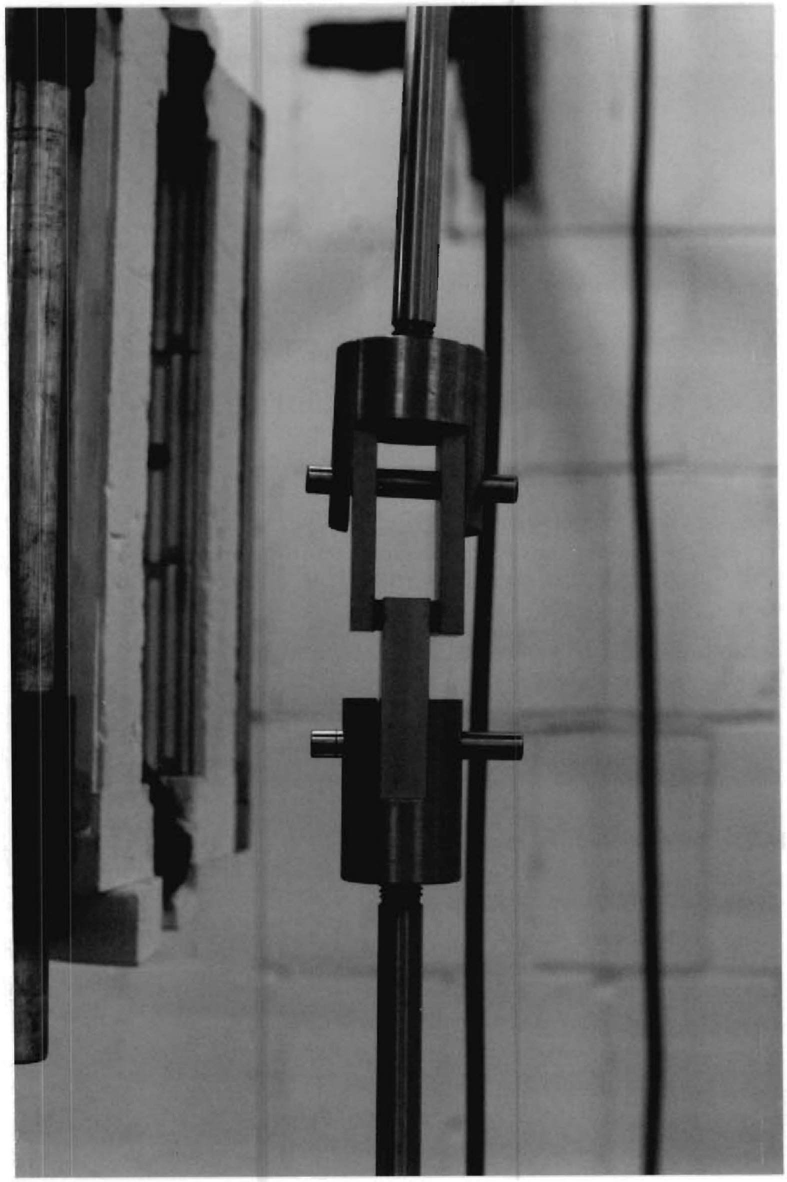

Figure 4. Double lap shear specimen held by grips fabricated for MTS machine (Top shaft shown loose in collet.)

Table 3. Specimen Identification Code

example:	R L N F 1
position:	1. 2. 3. 4. 5.

Position	Definition
1.	Testing Temperature R: Room temperature C: Cold temperature
2.	Specimen Assembly L: Double lap shear B: Butt joint
3.	Thermal Cycling Prior to Testing N: No thermal cycling C: Thermally cycled
4.	Structural Adhesive R: RTV 8250 S: Scotchweld F: Keene 6250 film SS: Scotchweld with silver surface prep SL: Stripline; Scotchweld 2216 bonds a three layer teflon sandwich to aluminum. Keene 6250 film bonds the teflon layers
5.	Identification Number 1, 2, 3 ..., distinguishes between identically constructed samples

Results

Most double lap shear specimens did not experience a simultaneous failure of both sides. In most cases, the specimen was loaded and a failure occurred at only one bond. Upon failure of the first bond, slack at the pinholes allowed the specimen to realign with respect to the vertical axis and compensate for unsymmetric loading. Since the testing machine was rate controlled with displacement feedback, the slack and resulting specimen movement produced a temporarily decreased load. After this adjustment, the load increased and the second bond was loaded to fracture. Consequently, most double lap shear specimens experienced two separate failures and thus, have different strengths for each bond.

Since both bonds of each double lap shear specimen used the same structural adhesive, bond line thickness and overlap area, theory predicts both sides should have failed at the same stress level. The different failure stesses of the two bonds may be attributed to unsymmetric loading and resulting misalignment after the first bond failure, or may indicate a bond integrity difference produced during specimen manufacturing.

Shear strength values for the first bond failure were calculated as follows:

$$\tau_1 = \frac{P_{1\ max}}{2A}$$

where: $P_{1\ max}$ = maximumum load at first failure

A = overlap area of bond

After the first failure, the specimen had only one bonded joint and thus, the specimen's total overlap area was reduced by one half. Consequently, strength values for the second bond were calculated as follows:

$$\tau_2 = \frac{P_{2\ max}}{A}$$

where: $P_{2\ max}$ = maximum load at second failure

A = overlap area of the bond

The load vs. displacement curves of specimens RLNF3 and RLNSS1 (Figs. 5 and 6) exemplify typical cases in which bonds of the double lap shear specimen experienced separate failures. Both curves show two load maximums. In the case of RLNSS1, both bonds failed at approximately the same stress level. On the other hand, the first bond failure of RLNF3 occurred at approximately 50% of the maximum stress experienced by the second bond. Again, the strength difference of the two bonds may be attributed to unsymmetric loading and resulting misalignment after the first failure, or may indicate a bond integrity difference produced during specimen manufacturing.

Double lap shear specimens RLCS1, RLNS1 and RLNS10 did not experience two separate bond failures. These specimens failed at one maximum load and then lost virtually all load carrying capacity. A typical example of this case was exemplified by the load vs. displacement curve of specimen RLNS1 (Fig. 7). Here, only one load maximum was noted.

Both the structural adhesive and the ferrite of specimens RLNS2, RLNS10, RLCS1, RBNS1 and RBCS2 failed (Fig. 8). With these failures it was impossible to conclude whether the structural adhesive or the ferrite block first yielded under loading. The structural adhesives of specimens RBCF1, RBCF2, RLCS2 and RBNS1 never failed. Failure occurred in these specimens only as a result of the ferrite failing under loading (Fig. 9).

Most butt joint stripline specimens failed where Scotchweld 2216 bonded the Cuflon or Duroid sandwich to aluminum. Here, specimens RBNSL1, RBNSL2 and RBNSL6 used a Cuflon sandwich, while RBNSL3, RBNSL4 and RBNSL5 used Duroid. RBNSL3 showed the only failure between the teflon sandwich layers. Here, Keene 6250 film bonded three layers of Duroid (Fig.10).

Table 4 gives the failure stress of each lap shear bond and the maximum failure stress for each specimen. Table 5 gives the maximum tensile strength of each butt joint specimen. Both Tables and give an average maximum strength and standard deviation for each structural adhesive and sample type. Figures 11 and 12 show bar graphs comparing these average maximum strengths. One may note from Fig. 12 that Keene 6250 film yielded, by far, the highest tensile strengths. Uncycled, butt joint specimens with Keene 6250 film failed at stress levels of more than 2.5 times greater than the next strongest tensile specimens,(uncycled with Scotchweld 2216). Keene 6250 film also produced the highest maximum shear strengths of double lap shear specimens tested at room temperature. Again, uncycled shear specimens using Keene film failed at stress levels over 2.5 times greater than the next strongest shear specimens (uncycled with Scotchweld 2216 and silver surface plating). Only lap shear specimens bonded with Scotchweld 2216 and tested at low temperature extremes exhibited strengths comparable to specimens bonded with Keene film.

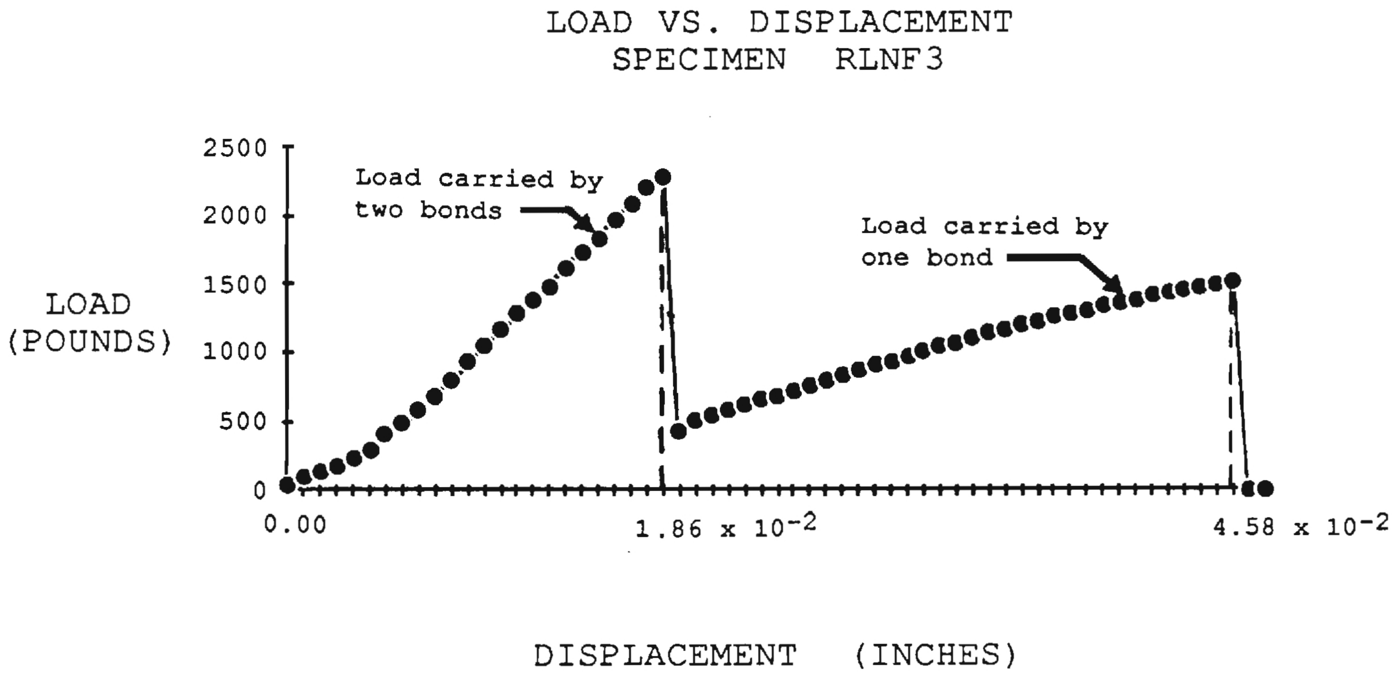

Figure 5. Load vs. displacement curve of specimen RLNF3. Bonds did not fail simultaneously. (Note presence of two load maximums.)

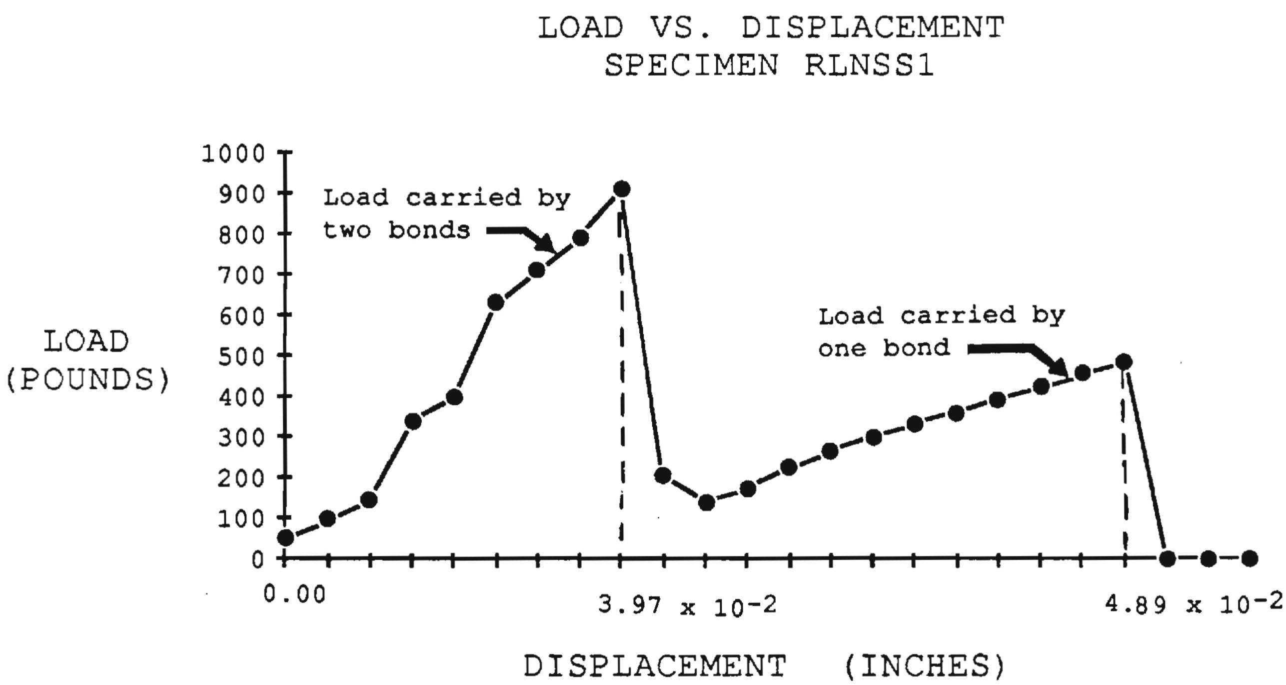

Figure 6. Load vs. displacement curve of specimen RLNSS1. Bonds failed at different loads but approximately the same stress level. (Note: $P_{2\ max} = 1/2\ P_{1\ max}$)

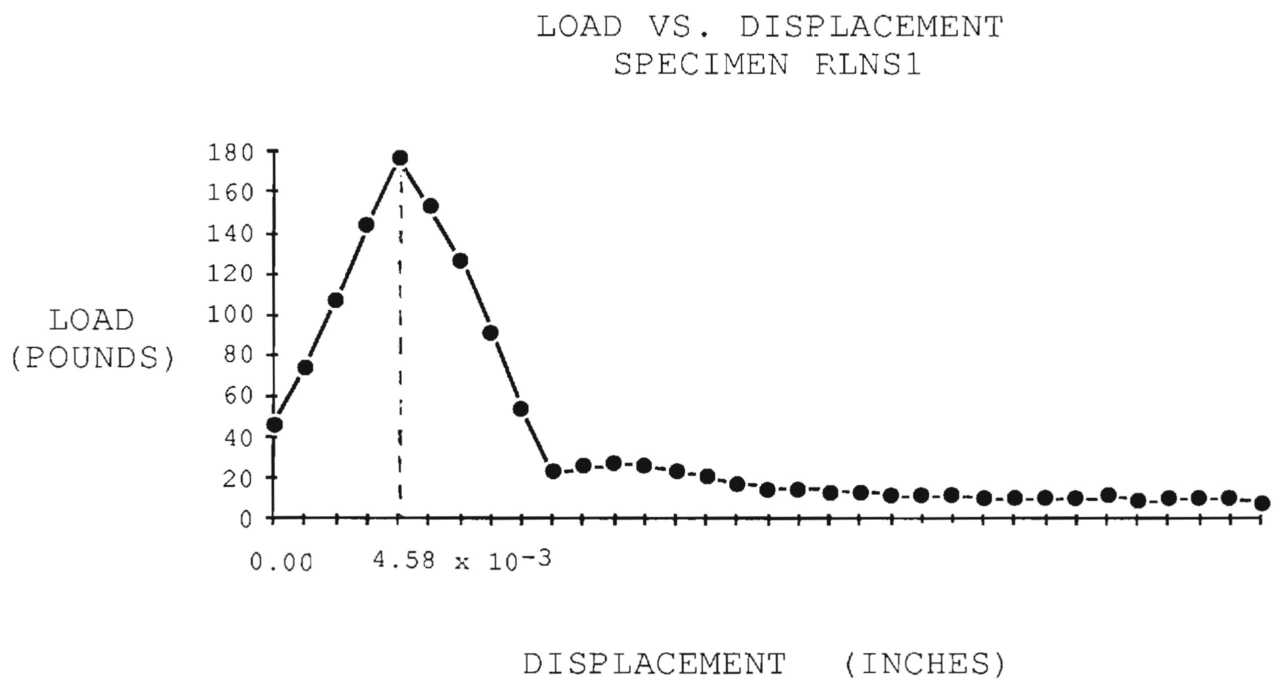

Figure 7. Load vs. displacement curve of specimen RLNS1
Failure occurred at one maximum load.

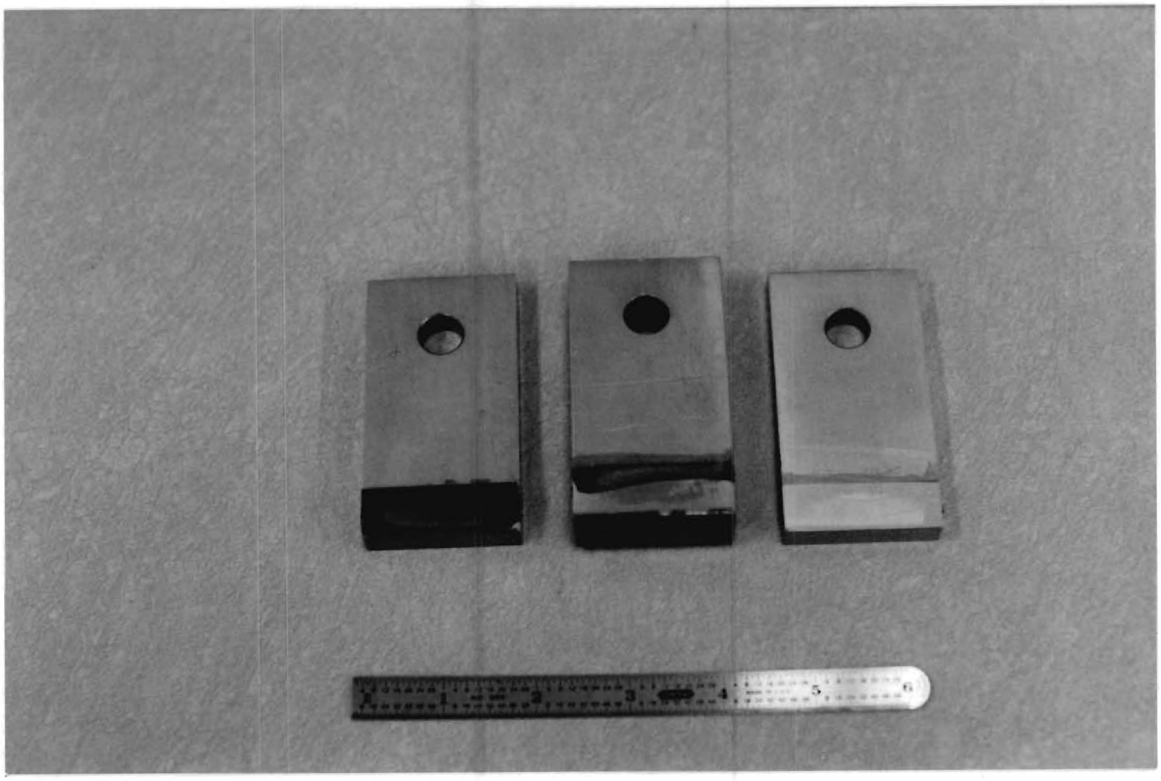

Figure 8. Failure of both the structural adhesive and the ferrite (specimen RLNS10)

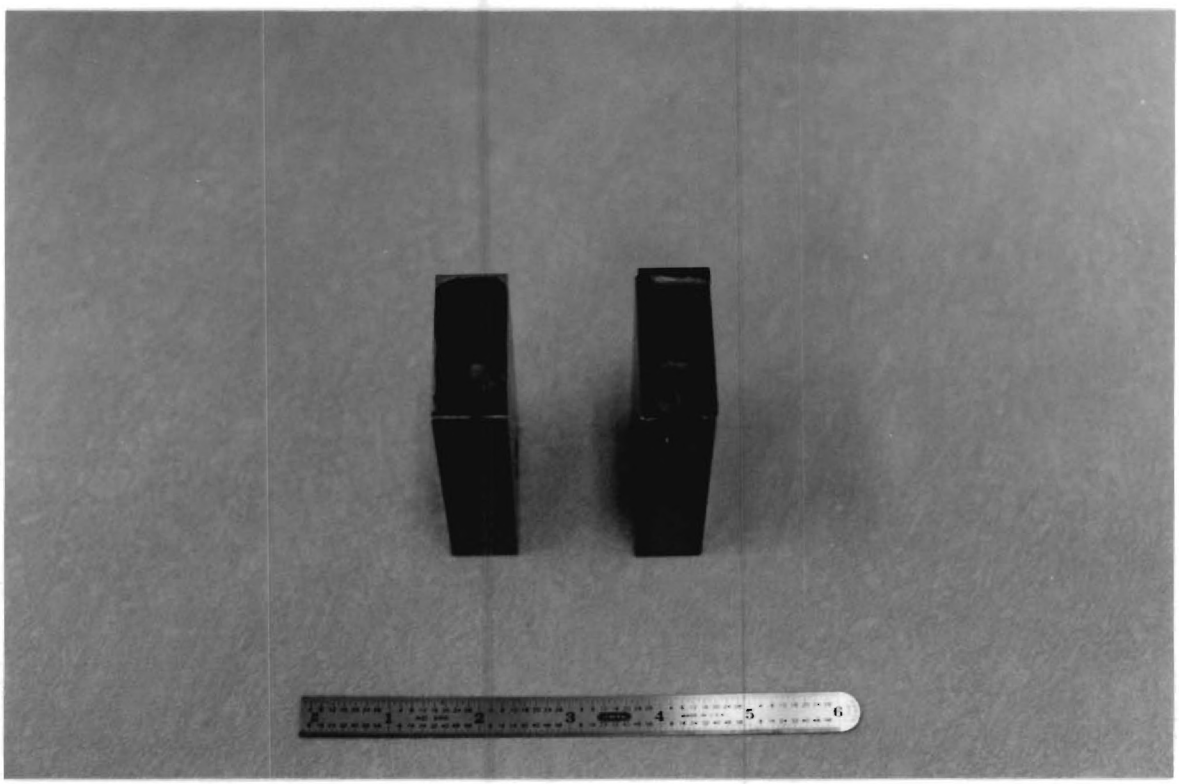

Figure 9. The ferrite failed under loading; no structural adhesive failure occurred. (specimen RBCF2)

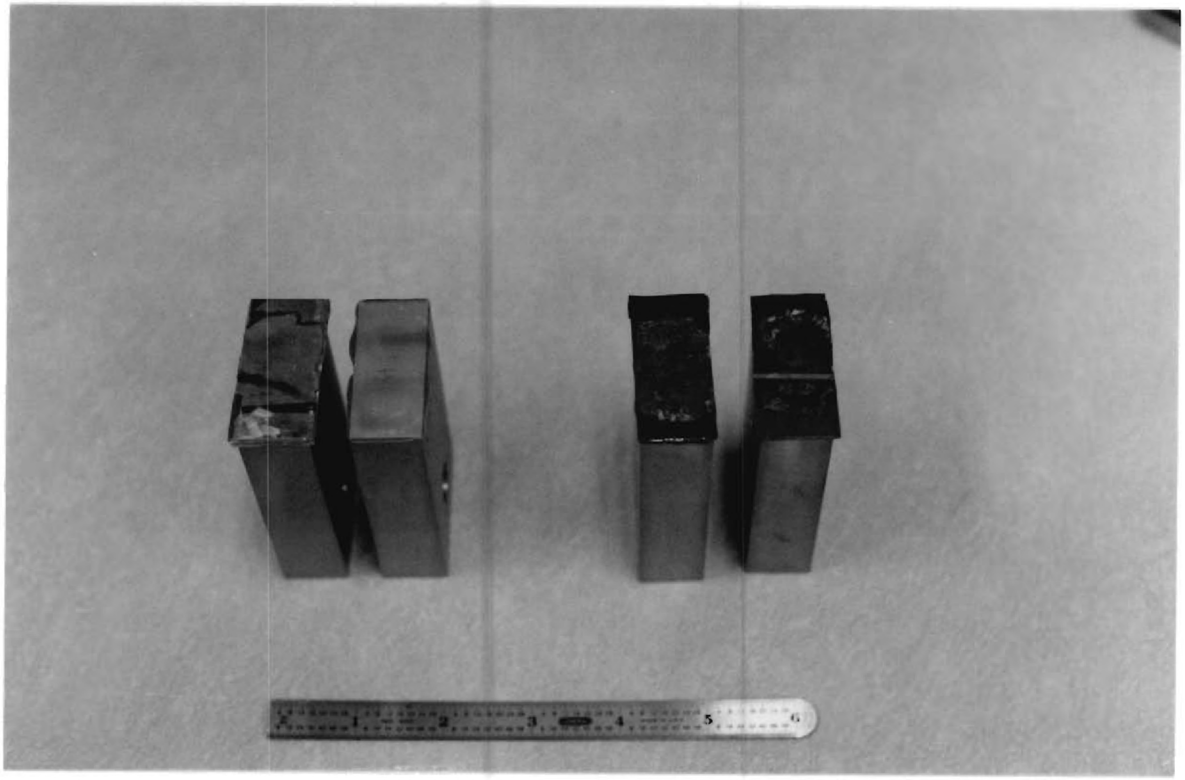

Figure 10. Stripline, butt joint specimens

A. Failure at aluminum - teflon interface bonded with Scotchweld 2216 (specimen RBNSL1)

B. The only failure at a teflon - teflon interface. Here, Keene 6250 film bonded layers of the teflon (Duroid) sandwich. (specimen RBNSL3)

Table 4. Shear Strengths for Specimen Groups

Specimen I.D.	τ_1 (psi)	τ_2 (psi)	τ_{max} (Specimen) (psi)	τ_{max} (Average for group) (psi)	Standard Deviation (psi)
RLNF_					
1	1413.1	1327.4	1413.1	1510.9	186.4
2	1231.1	1393.0	1393.0		
3	1299.5	1726.6	1726.6		
RLCS_					
1	241.5	-	241.5	385.1	253.8
2	263.8	678.3	678.3		
3	F.B.T.	-	-		
4	235.9	182.8	235.9		
RLNSS_					
1	570.2	556.9	570.2	589.9	290.0
2	327.3	996.6	996.6		
3	153.5	321.0	321.0		
4	166.8	471.8	471.8		
RLNR_					
1	F.B.T.	-	-	9.5	1.4
2	F.B.T.	-	-		
3	F.B.T.	-	-		
4	10.5	8.4			
RLNS_					
1	104.7	-	104.7	364.6	324.3
2	580.6	1119.4	1119.4		
3	90.0	90.7	90.7		
4	109.6	224.7	224.7		
5	286.1	513.6	513.6		
6	92.8	150.7	150.7		
7	178.0	141.0	178.0		
8	243.3	375.5	375.5		
9	76.8	221.9	221.9		
10	666.5	-	666.5		

F.B.T. = Failure Before Testing

Table 4. Shear Strengths for Specimen Groups (continued)

Specimen I.D.	τ_1 (psi)	τ_2 (psi)	τ_{max} (Specimen) (psi)	τ_{max} (Average for group) (psi)	Standard Deviation (psi)
CLNS_					
1	425.0	2021.1	2021.1	1522.3	471.8
2	427.8	1462.8	1462.8		
3	316.1	1083.1	1083.1		

Table 5. Tensile Strengths for Specimen Groups

Specimen I.D.	Tensile Strength (psi)	Average Strength for Specimen Group (psi)	Standard Deviation (psi)
RBNSL_			
1	1104.5	1128.2	204.6
2	891.4		
3	1150.6		
4	1465.6		
5	949.1		
6	1207.8		
RBNR_			
1	145.2	235.0	85.4
2	124.7		
3	279.2		
4	348.5		
5	272.2		
6	240.1		
RBNSS_			
1	231.7	318.3	122.4
2	404.8		
RBNF_			
1	3179.6	3197.7	25.6
2	3215.8		
RBNS_			
1 (2214)	67.0	280.8	400.3
2	42.8		
3	134.9		
4	878.4		
RBCS_			
1	-	344.3	
2	344.3		

Table 5. Tensile Strengths for Specimen Groups (continued)

Specimen I.D.	Tensile Strength (psi)	Average Strength for Specimen Group (psi)	Standard Deviation (psi)
RBCF_			
1	25.1	19.1	8.6
2	13.0		
RBCR_			
1	26.1	38.9	19.7
2	24.2		
3	38.1		
4	67.0		

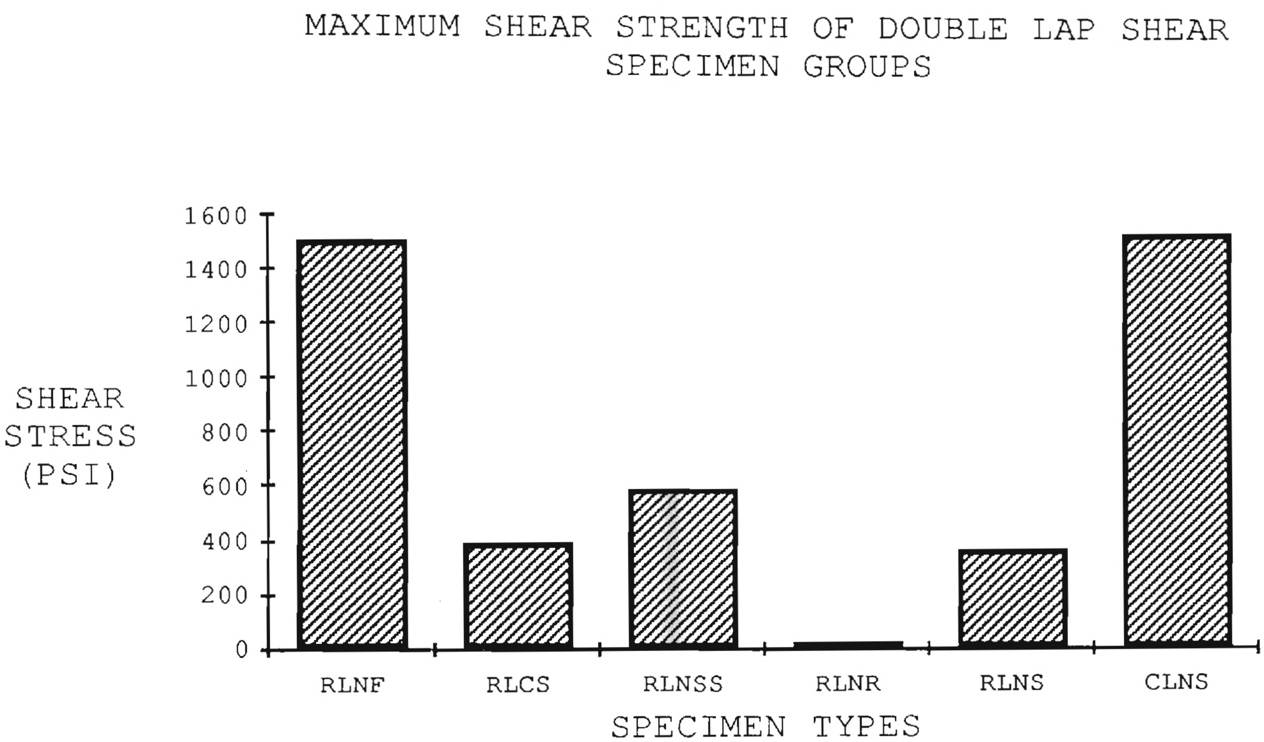

Figure 11. Shear strengths of Specimen Groups

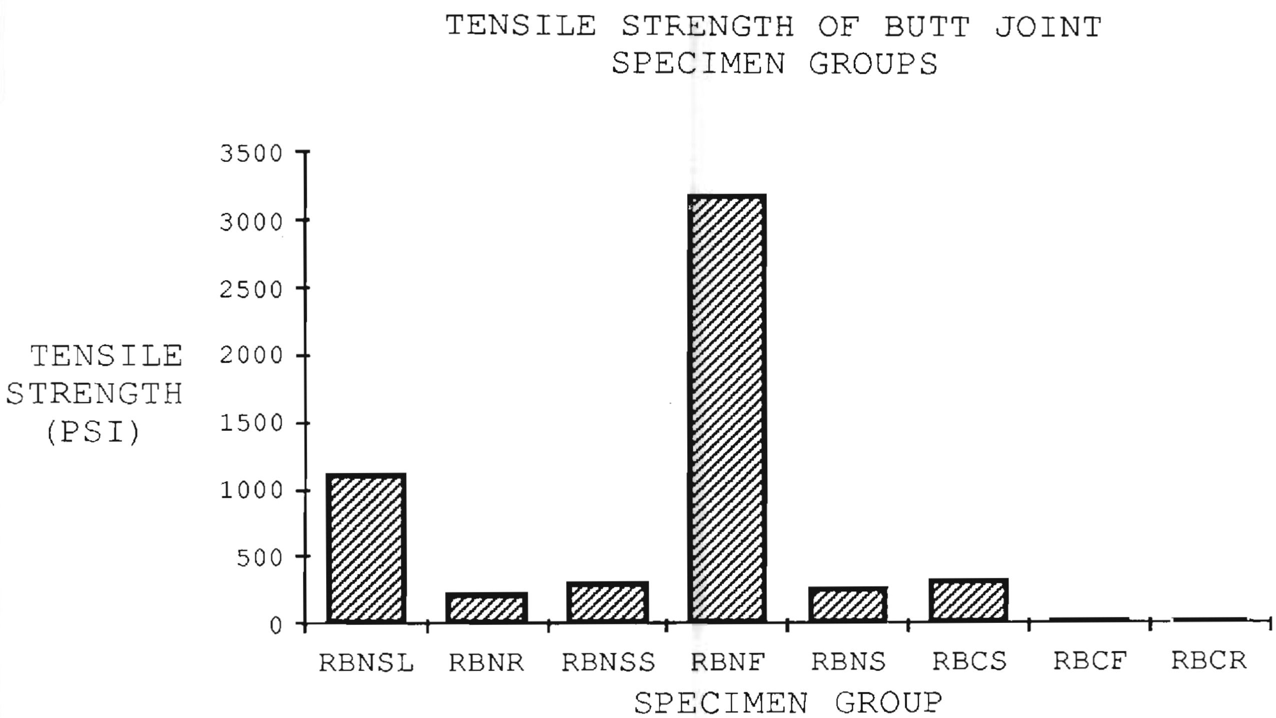

Figure 12. Tensile strengths of specimen groups

Conclusions

The maximum strengths of the butt joint and double lap shear specimens are given by tables 4 and 5 respectively. As previously discussed, most double lap shear specimens experienced two separate failures and thus, exhibited different strengths at each bond. The difference in failure stresses of the specimen's two bonds may be attributed to unsymmetric loading and resulting misalignment after the first bond failure, or may indicate a bond integrity difference produced during manufacturing.

Figures 11 and 12 compare maximum shear and tensile stengths for each structural adhesive and specimen type. These figures indicate that Keene 6250 film produced, by far, the highest strength bonds of all adhesives tested at room temperature. More specifically, Keene 6250 film failed at stress levels greater than 2.5 times the next strongest adhesive during both shear and tensile testing. Only double lap shear specimens bonded with Scothweld 2216 and tested at low temperature extremes failed at comparable stress levels.